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P01/7700 0.00-0420735.3 CHEQ

Request for grant of a patent

17 SEP 2004

The Patent Office
Cardiff Road
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South Wales NP10 8QQ

1. Your reference
1909202/AM

2. Patent Application Number
0420735.3

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

Scientific Generics Limited
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Patents ADP number *(if known)* 07970296002

If the applicant is a corporate body, give the country/state of its incorporation

Country: **England**
State:

4. Title of the invention

2D Positioning Sensor

5. Name of agent
"Address for Service" in the United Kingdom to which all correspondence should be sent

Beresford & Co
16 High Holborn
London WC1V 6BX

Patents ADP number 00001826001

6. Priority: Complete this section if you are declaring priority from one or more earlier patent applications filed in the last 12 months.

Country	Priority application number	Date of filing

Patents Form 1/77

7. Divisionals, etc: Complete this section only if this application is a divisional application or resulted from an entitlement dispute.

Number of earlier application — Date of filing

8. Is a Patents Form 7/77 (Statement of inventorship and of right to grant of a patent) required in support of this request?

Yes

9. Enter the number of sheets for any of the following items you are filing with this form.

Continuation sheets of this form	
Description	5
Claim(s)	
Abstract	
Drawing(s)	4 + cf

10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent *(Patents form 7/77)*	**X 1 + 1 copy**
Request for preliminary examination and search *(Patents Form 9/77)*	
Request for Substantive Examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application

Signature Beresford & Co

BERESFORD & Co

Date 17 September 2004

12. Name and daytime telephone number of person to contact in the United Kingdom

MACDOUGALL; Alan John Shaw

Tel: 020 7831 2290

SCIENTIFIC _GENERICS

INITIAL PATENT FILING

Subject: 2D positioning sensor

μ-Track: a new position sensing technology

A new position sensing technology has been disclosed in the patent application "2D positioning sensor" filed on 27/02/04. This technology, μ-Track, can measure continuously, over a large range of displacements, the position of a magnet located a few centimetres away from a long PCB sensor head. It provides precision positioning even through thick barriers of non-magnetic material e.g. aluminium, non-magnetic steel, etc.. μ-Track enables the construction of low-cost 1D, 2D and rotational sensors with resolutions typically 0.01% of full scale, 1kHz bandwidth and low cost (about €10). The accuracy and performance of this new sensor is practically unaffected by variations in temperature, the strength of the magnet or the distance between the magnet and the sensor head plane.

μ-Track consists of four essential elements:

- a permanent magnet, whose linear or angular position is to be sensed;
- a soft magnetic film;
- a piece of printed circuit board (PCB) material with tracks forming the inductive position or angle sensor;
- signal processing electronics, preferably in the form of ASICs.

To understand how μ-Track works, let's review the principles of inductive position sensors.

Inductive position sensors

An inductive position sensor correlates the amplitude of AC signals induced in a pair of receive coils with the position of a moving target. An AC electromagnetic field is generated by a transmit coil integrated in the same plane as a pair of receive coils.

The mutual inductance of the transmit/receive coil(s) is designed to be close to zero so that there is a negligible break-through signal in the absence of the target. The coil(s) can be cost effectively fabricated as conductive tracks on a printed circuit board (PCB). In this case, a low mutual inductance can be achieved by using coils with the physical geometry of 'sine' and 'cosine' curves as shown in Fig.1, for example. The received signal from the coil(s) depends on the position of the target

with respect to the PCB tracks. As shown in Fig.1 the response of each receive coil to the movement of the target across the PCB tracks will vary as a 'sine' or 'cosine' function respectively. The amplitude of such response will generally depend on the details of the target, the distance between the target and the PCB tracks, the degree of lateral offsets, and so on. A ratiometric signal processing approach allows the use of a simple 'arctan' function to provide a linear sensor output that is insensitive to the absolute signal levels, as shown in Figure 1.

One specific example of a moving target is a resonant target. Such a target is typically a circuit consisting of an inductor and a capacitor, with a resonant frequency in the range 100kHz to 10MHz. Scientific Generics has been developing resonant target inductive position sensors for more than a decade, and has several granted patents in this area.

A major limitation of inductive position sensors comes from the shielding of the AC electromagnetic field by electrically conductive plates. As a result, the technique of inductive sensing will only work well when there are no metallic walls in the space between the target and the coils. This effect limits the practical application of inductive position sensors – they can not be used, for example, to measure the position of a piston in a pneumatic cylinder.

Magnetic field position sensors

The use of a permanent magnet attached to the object of interest for sensing purposes is normal practice in several applications where metallic parts surround the object. Usually, a point magnetic sensor detects the magnetic field from the moving permanent magnet. For example, in pneumatic cylinder applications two Hall effect sensors are typically attached to the cylinder case to sense the position of the piston as it nears the desired end positions.

A major limitation of current magnetic field position sensors is the lack of a practical continuous sensor. Most attempts to produce such a sensor consist, in fact, of arrays of discrete point sensors.

Magnetic field position sensors are based on calibrating the dependence of the measured value of the magnetic field against the mutual distance between the magnet and the point magnetic sensor. This calibration will be affected by the size of the magnet, sensitivity of a particular sensor, angle between the magnet and the sensor surface and other offsets. The sensitivity of a magnetic sensor usually varies significantly with the temperature; high temperature will also affect the amplitude of the magnetic field generated by the permanent magnet. Thus the temperatures of the sensor and the magnet should be taken into account to produce software correction of the calibration curves.

Soft magnetic film as a continuous magnetic field position sensor

A soft magnetic film can be used as a continuous magnetic field position sensor as described below and shown in Figure 2. Essentially, the permanent magnet induces an inhomogeneity in the parameters of the soft magnetic film in a region above the

magnet's pole where the magnetic field is predominantly perpendicular to the film surface. The position of this inhomogeneity is insensitive to the temperature, parameters of the magnet, or the properties of the magnetic film. Instead it is determined only by the geometrical position of the magnet in the respect to the soft magnetic film. Indeed in the region of the inhomogeneity the permeability of the magnetic film is significantly different to the value of the permeability outside this spot.

How can this be sensed?

The presence of a soft magnetic film in close proximity to the tracks on a PCB will affect the inductance of both transmit and receive coils. An homogeneous magnetic film will not disturb the balance of the transmit/receive coil(s) – their mutual inductance will remain close to zero. However, as the magnet causes a significant inhomogeneity in the magnetic properties of the soft magnetic film, it will induce non-zero mutual inductance in the transmit/receive coil(s). The signal in the receive coil(s) is determined by the position of the inhomogeneity with respect to the tracks on a PCB, just as it would be for a moving target.

This in essence is μ-Track: take a common inductive position sensor and replace the target with a permanent magnet and a film of soft magnetic material (see Fig.2). The position of the magnet can be sensed through non-magnetic materials, e.g. the aluminium walls of a pneumatic cylinder.

μ-Track performance

We have constructed a demonstration system by taking an inductive position sensor and replacing the target with a thin film of soft magnetic material and a magnet. We have also tested it using a commercially available pneumatic cylinder by simply attaching the magnetic film and inductive position sensor to the cylinder case (see Fig.2). In both cases, the sensor functions very well, with reasonable linearity, reproducibility, and a response time limited only by the signal processing electronics.

As discussed above, μ-Track sensor does not measure the exact value of the magnetic field generated by the magnet and thus does not rely on calibrations. It is insensitive to temperature variations, the size and the strength of the magnet, the exact distance between the magnet and the surface of the film, lateral offsets and the orientation of the magnet. Furthermore we have demonstrated that the μ-Track sensor is insensitive to the fringe field of remote permanent magnets if such magnets are located further than five to ten centimetres away from the surface of the soft magnetic film. A thicker (~0.5mm) soft magnetic plate made from materials like silicon-iron could be used to shield external fringe magnetic fields if necessary. The inhomogeneity spot induced on the surface of the soft magnetic plate facing the tracked magnet could be used as a moving target for the μ-Track sensor.

The relative displacement of the magnet can be measured with the μ-Track sensor continuously over a large range of displacements from a few millimetres to over a few meters. The necessary resolution and accuracy is provided entirely by the geometrical design of the conductive tracks on the PCB sensor head.

Market opportunities

The μ-Track sensor enables low-cost long-range 1D, 2D, and rotational sensors with high performance to be made. Effectively μ-Track can be considered as an electronic calliper working through a metallic enclosure and can be used to measure the movement of the permanent magnet attached to the target. Some further examples of rotation encoders based on μ-Track are shown in Fig.3 and Fig.4.

μ-Track technology is of interest to pneumatic cylinder manufacturers, sensor manufacturers which supply solutions for industrial control systems, the automotive industry, aerospace, and white goods manufacturers and sensor manufacturers of generic rotation encoders or linear sensors.

The development of the μ-Track sensor represents an exciting opportunity to resolve some unanswered needs for non-contact position sensing.

The most immediate market opportunity for μ-Track is as a replacement for the existing two point sensors used with pneumatic cylinders. Manufacturers and end-users of pneumatic cylinders would prefer a continuous position sensor which would enables a range of different stop points to be set up in software. This will increase productivity and improve the flexibility of many industrial automation applications.

Description of Figures:

Fig. 1. Example of the design of conducting tracks on a PCB for a ratiometric inductive position sensor. A pair of 'sine' and 'cosine' receive coils has zero mutual inductance to each other and to the rectangular transmit coil. The moving external target induces additional mutual inductance between coils. As a result 'sine' and 'cosine' signals are induced in the receive coils. The amplitudes of the signals are affected by the parameters of the target, distance between the target and the PCB sensor head, lateral offsets, and so on. The ratio between the induced signals in the 'sine' and 'cosine' receive coils is equal simply to the tangent of the phase of the target position. The phase is measured in respect to the period of the tracks on a PCB.

Fig. 2. An example of the μ-Track sensor for pneumatic cylinder is shown on the left. All pneumatic cylinders already have a permanent magnet attached to the piston. The diagram on the right shows the formation of the spot of inhomogeneity in the in-plane magnetic field generated by the local permanent magnet. This spot corresponds to the induced inhomogeneity in the parameters of the soft magnetic film in a region above the magnet's pole where the magnetic field is predominantly perpendicular to the film surface. Such a region of inhomogeneity in the permittivity could be used as a target for the inductive position sensor shown in Fig. 1.

Fig. 3. Example of a rotary encoder for an 'intelligent' bearing. Such a configuration could be used as a steering position sensor for automotive applications. Linear resolution along the perimeter of the circle with the μ-Track sensor provides a direct

measure of angular rotation. A pair of receive/transmit coils of the inductive position sensor is shown only schematically.

Fig. 4. Further examples of a rotary encoder based on the μ-Track sensor. The permanent magnet is fixed asymmetrically inside the axle. A 2D version of the μ-Track sensor can be used if axle is moving along the axis of rotation. Displacement of the inhomogeneity spot along the axis will measure linear movement of the axle; displacement along the perimeter will measure angular rotation.

Fig.1

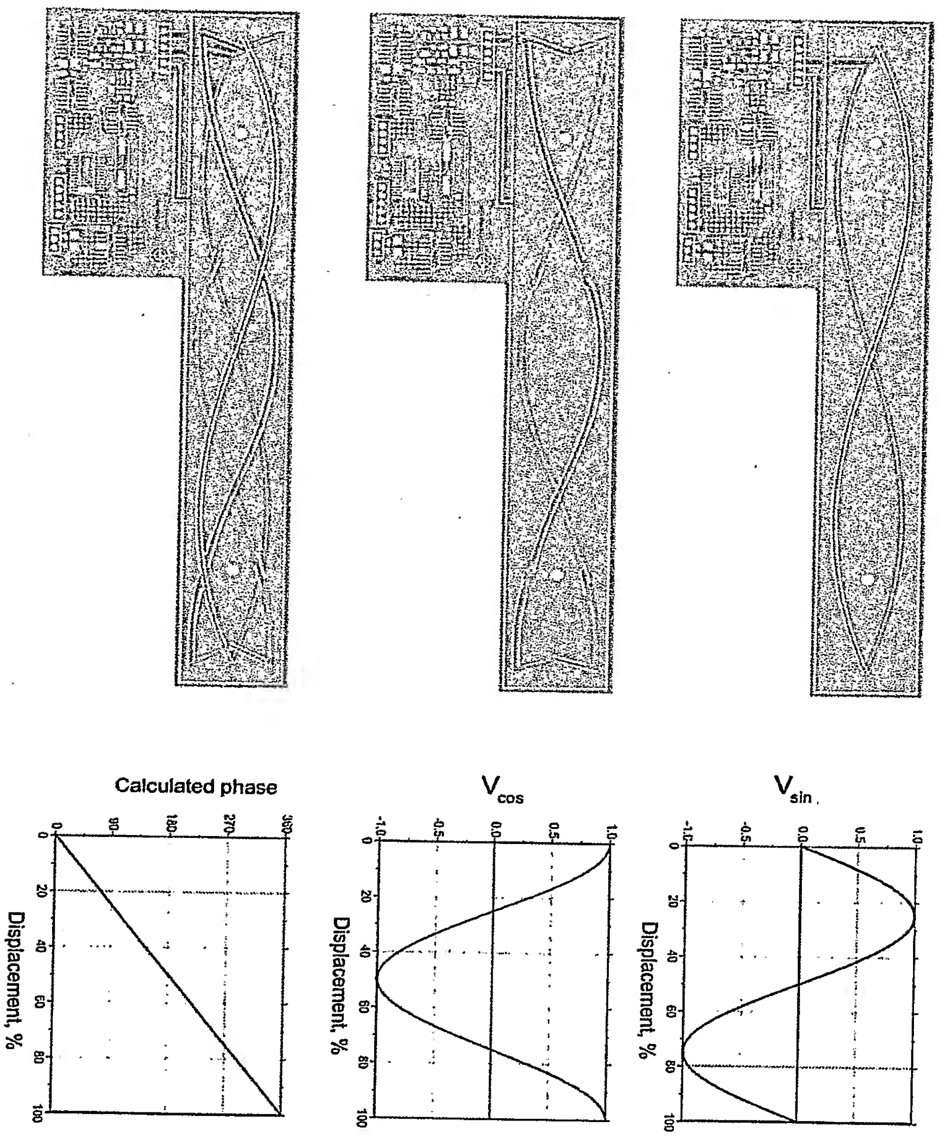

Calculated phase
V cos
V sin
Displacement, %
Displacement, %
Displacement, %

Fig. 2

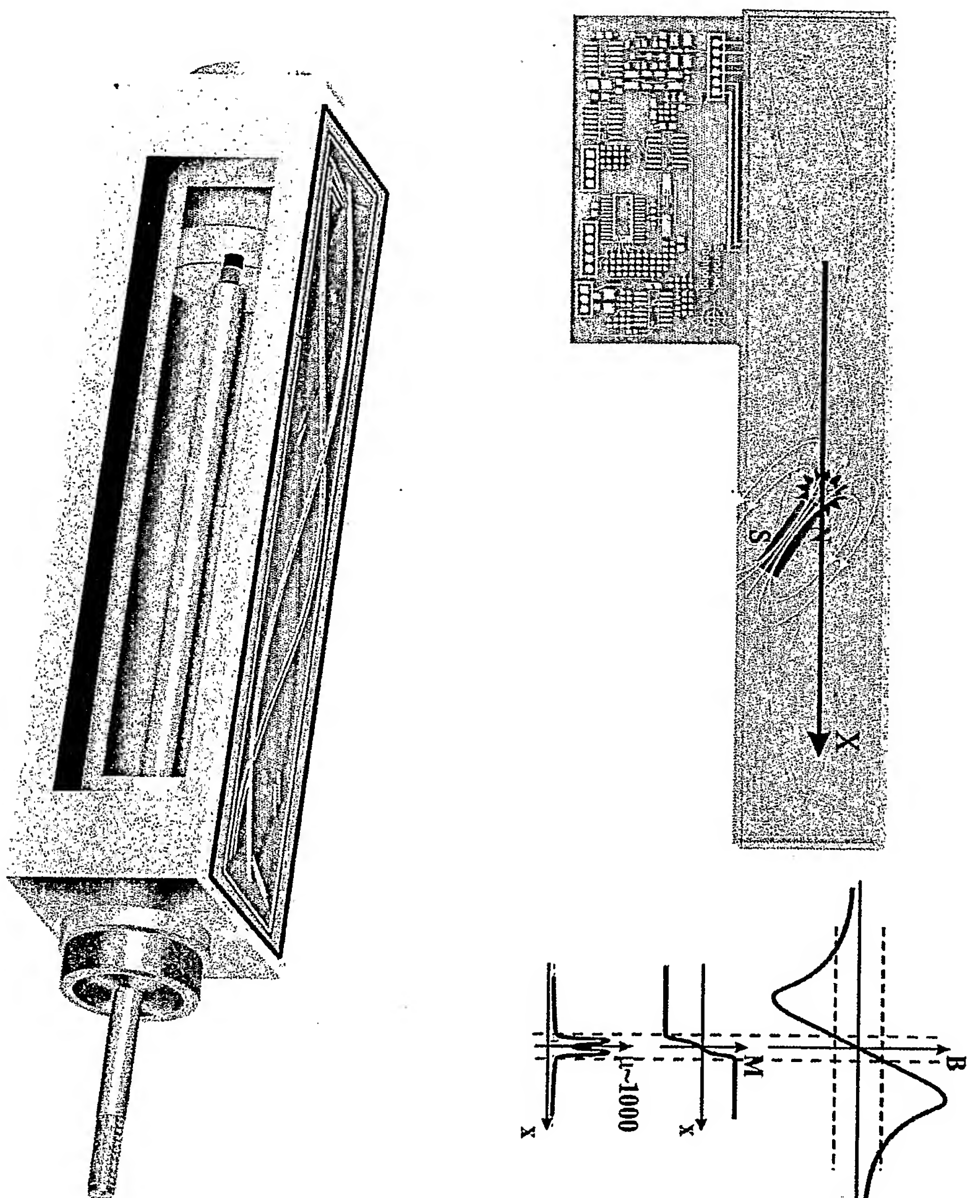
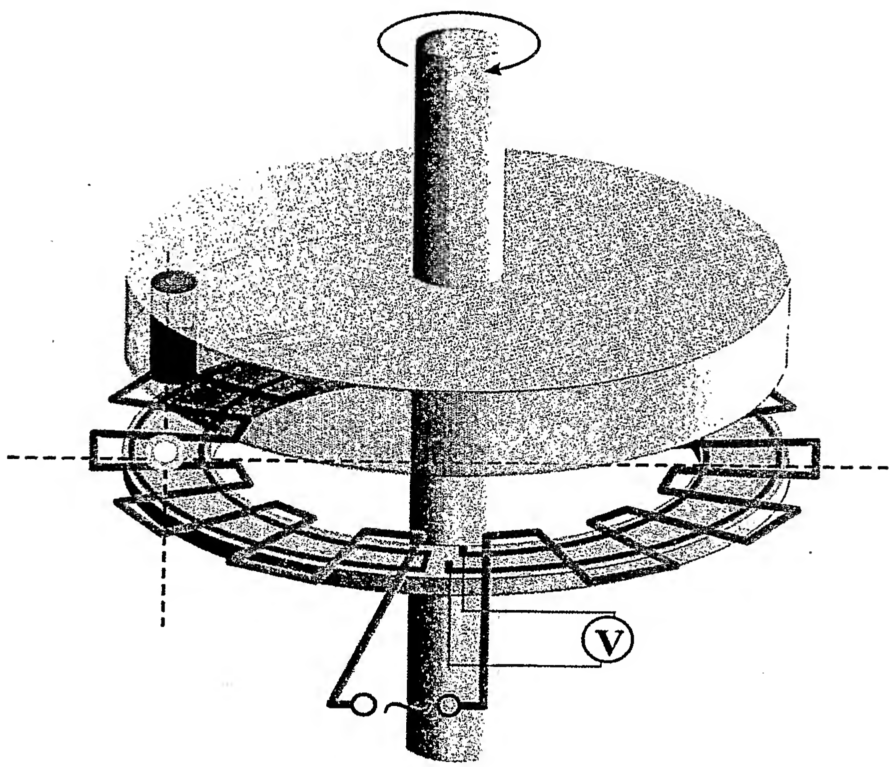


Fig. 3



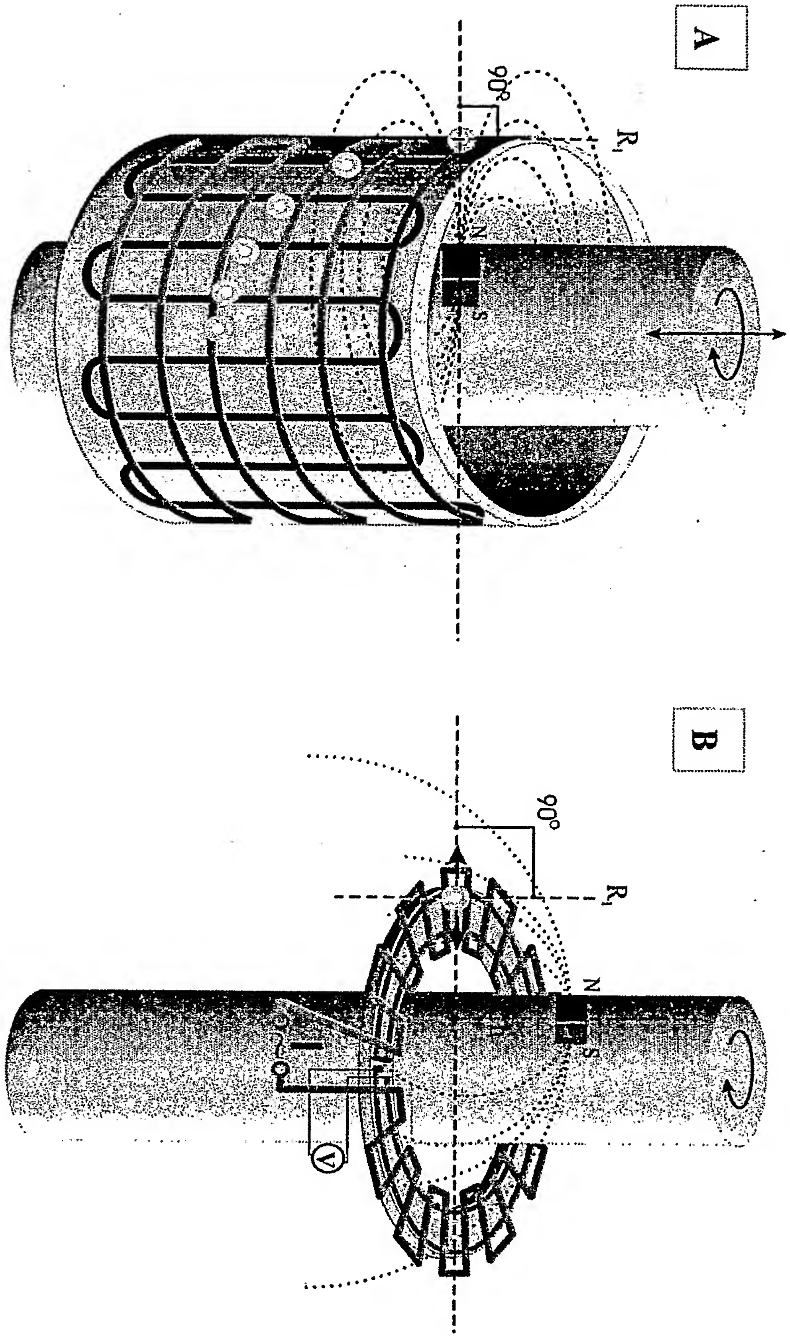


Fig. 4